Mapping of Lineaments for Ground Water Targeting Using Mss Satellite Data in North-West of Talata Mafara, Zamfara, Nigeria

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Abstract: **Groundwater detection and supply in underlain crystalline basement complex rocks involves and require satellite image's lineaments discernment, detection, classification, mapping and analyses of l their patterns and orientation in region of Talata Mafara, Zamfara State, North Western Nigeria. This study is carried out as application of remotely sensing techniques for discernment and mapping of lineament for efficient ground water exploration and management. The primary data used is Groundwater detection and supply in underlain crystalline basement complex rocks Landsat Mss –ve image transparency while the secondary data are geological maps, hydrological maps and topographic maps.. In this study, procum-2, an optical mechanical device to manually interpreted the digitally processed image, the basic element of interpretation which are jointly used for lineaments discernment, classification, mapping and analysis for structural map production. The extracted lineaments are statistically further analyzed to determine their lengths densities, intersections and orientations, and the result obtained is used to generate structural map for lineament density, frequency, direction and intersection, and represented with Rose diagram. The relationships of the mapped lineaments are synthesized from the registered image features as projected onto a topographic base map of the study area based on geologic and geomorphic interpretation and supported with ground truthing. The lineament analysis indicated that the area has numerous long and shot fractures whose structural strength are mainly in the NNE-SSW directions at an angle of 10-eas30°. The cross-cutting and intersectional lineaments are relatively high in areas around North-East, Central and South-East locations, (are projected to be productive hydrologic zones in the study area) and are relatively low in the other areas. The lineaments mapping led to delineation of ground water localised zones and are mostly feasible for further geo-physical survey, prospecting for sitting of productive and sustainable supply boreholes. It is found that of the 20 (with 4 in each segmented parts A-E) boreholes sunk in the prospective zones 15 constituting 75% of the total (with 3 in each segmented parts A-E) are found to be productive.**

Key words: **Groundwater, Basement complex rocks, Detection, classification, Mapping, Analysis , and structural map.**

I. INTRODUCTION

The various annals and manual of photogrammetric and remote sensing documentations (especially the first editions of 1981 and subsequent editions) posited that there has been confusion in literatures regarding various definitions of lineament. The meaning has been ascribe and restricted linear-like features occurring in satellite images for analyses in geologic remote sensing. It includes fracture traces and other micro and macro fractures, mega joints, etc. which are generally embodied in lineament description. They are also used in multidisciplinary for features in basement complex rock for small to large scale images as well as aerial photographs of places covered with dense vegetation with considerable over burden such as soil. The details on lineament definitions were contained in the proceedings of the first and second international conference on Basement Tectonics published by the Basement and Tectonics Committees in 1979, and in the proceedings of the international conferences heldon Basement Tectonics published in 1981 and the fourth one in 1984. Another key work on the progress made in using satellite observation is the proceeding of the 5th pecore symposium on remote sensing (Denish et al., 1981) which features satellite structural geology. The pages from 1370 to 1825 provided a table summarizing applications, data sources, precautions and limitations to be aware of and adopted in using satellite structural data in geologic linear features identification and mapping. O'Leory et al.,(1976) and Sabins, (1978) defined lineament as a mappable single or composite linear features on a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship that differs distinctly from the pattern of adjacent features to presumably reflect subsurface phenomena. The term according to him, is an adjective that describes the line like character of some object or objects. Lineament could be used in general term to include all linear features (Chivasa, 1999). In line with the above definitions, remotely sensed data for lineament mapping is primarily based on technical enhancement procedures and reference level of the interpreter that involve the use of digital imaging systems and optical processing of large array of data processed and handled with computer to produce ready to interpret images (Kinabo,1999). According to Arlegui and Sorian, (1998) and Akmen and Tufekc, (2004), Lineaments are associated with displacement and represent fault trace or fault zones. Lineaments study could be divided into local and regional categories. The high altitude aircraft and satellite based small scaled observations, are generally most applicable to regional to regional category whereas, low altitude aerial photographs and ground based remote sensing apply to local studies. Regional studies typically cover an area to 1000 Km^2 (Alia and Piirasteto, 2004). Kinabo (1999) further defined and gave nomenclature of lineament features for subsurface features character of lineament include fracture traces with significance to ground water prospecting. This involves scaling on linear traces (with or without obvious displacement on the surface feature), sizes and mapping and based on other possible related identified structures. They include:

i. Joint traces of few cm(s) to tens of m length for outcrop on map, small scale and large scale aerial photos image that could be observed and described.

ii. Fracture traces that have l00m to 1.6km length on map with aerial photos define large scale topographical maps joint concentration of about 33m wide.

iii. Lineaments are short (1.6-10km) on topographical maps, small aerial photos to define small scale aerial photos, broad zone of 2few km wide, of disrupted nodes. There also Intermediate (10-100km) on topographical maps with relief model (1:250,000) to define concentration fracture zone long greater than (>) Long (100 500km) on satellite images and small scale relief model to define petrographic province aligned volcanic centre rift valleys. Moreover, the Mega lineament (500km and above) on satellite imagery; mosaic of pictures elements (pixels) of image to define continental structures as much as 100km wide.

The major task of the analyst according to Chevasa, (1999) and Newton, (2007) is in the identification, delineation and documentation of temporal and spatial variation on the image of major distribution of abundant geological features using geologic enhanced band 5, 6 and 7 that generate good results, for detailed interpretation, classification and mapping.

II. STATEMENT OF PROBLEM

Lineaments are advantageous for natural resources prospecting in hydrologic and hydro geological mining as they portray depositional concentration zone of water, minerals and natural gas as they have been successfully used for location of groundwater in basement complex of semi-arid region where there is acute water shortage. Satellite images including USA Landsat conception, have been used to identify several sets of linear features that provided basis for the definition of structure zones, trends and fractures traces, system and pattern that helped in defining areas of major dislocation, structural weakness with or without significance. Talata Mafare area are tectonically reworked by Pan African orogeny with imprints of deformation for which the basement complex resulted in lineament prone areas and therefore landsat image can be used to map underground water.

The Sudano-Sahelian, semi-arid region suffered from acute water shortage because of its geographic location, is one of the most critically water sensitive zone resulting from man induced climate change effect and anthropogenic activities of human induced problems. The lineaments (faults and fissures when indicated in image, are used for structural map production that helped in location prospecting of underground water resources in the area.

Study Need

i. There is the need to use remote sensing technique to spatially and temporally map lineaments fracture and fracture traces, and joints to identify lineament concentrated ares.

ii. Recent earth tremors was triggared in the basement complex that have been naturally tectonically stable, hence the is need to define lineaments within the earth crust.

Study Area

Talata Mafara is located between latitude 12°05^{1}N and 12°36^{1}N, longitude 6°03,E and longitude 6°33',E respectively (fig. 1 in appendix 1) at the boundary between rocks and the basement complex rocks in the sub-Saharan region of West Africa. The study area covers 1,860km^2 reflecting regional based study. The area is chosen for the following reasons

i. The study area is located on preterozoic mobile belt West Africa Craton (1,800± 200my). It is a polycyclic mobile belt, reworked upon by orogenis of tensional forces which resulted dislocation of faults, fractures fissures, etc. in the basement rocks. The area was rejuvenated and marked with overprint of events.

ii. The study area is located in the Sudano- sahelian zone and therefore a representative of the potentially water critical events of unexpected water resources shortages in related part of the world, due to prevailing global climatic change effect. Thus, the area's lineament traces could be used as potential area of water presence.

Climate

The climate and climatic variable do considerably influence environmental study of any area. The resulting effects are usually manifested through the major variables namely evapotranspiration, temperature and rainfall. The climate of the area is characterized by high rate of evaporation, transpiration and could use low amount of rainfall.

With 2019 climate data obtained from the nearest synoptic station Department of Meteorology Oshodi (nearest synoptic station), the mean annual air temperature of 28.1°C is recorded from the mean annual minimum and maximum temperature of 35.5^o C and 210°C respectively. Furthermore, the mean annual rainfall is l000mm for the area, results in negative water balance. Ther is therefore high propensity for acute water shortage in the area over time.

Aim and Objectives

This study use landsat remotely sensed data together with secondary data are used in generating and analyzing lineaments for structural map production in the area. The specific objectives are to:

- use Landsat multispectral (MSS) data for lineament mapping the fractures, fracture traces extent, directions, using manual analysis techniques.
- identification of the surface and invariably subsurface lineaments, map them based on the geomorphic, geologic and hydrologic analysis indices together with ancillary data and field work observation for location of ground water based on inferences drawn.
- evaluate mapped lineaments and characteristics such as fracture trends, traces, patterns, and directions, and their characteristics based on their measured frequency is used for groundwater inference and deduction.

III. LITERATURE REVIEW

The international reference catalogue papers on lineaments are compendium of various proceeding volumes of international conferences on Basement Tectonics. The proceedings of the first tectonics J.Y Benjamin, and published by the Utah Geological Association, Pub. #5, in 1976. Other subsequent ones and related researches are published in journals of Photogrammetry, Engineering, Environmental Science, Geography, Geology, Remote sensing, Geographic Information Systems, Annals and Bulletin for American Association of Petroleum Geologist amongst other.

In study carried out by Chivasa (1999) on post- karoo fault pattern in Hwange Coal Field located in the Wesictern extension of the mid-Zambezi in North-West Zimbabwe, South Africa, lineaments identification and analysis of landsat images were used to detect faults and analyzed their relationship in the regional fracture trend and zone. The technique offered procedure for analysis of subsurface features through surface correlation inference since they are invisible to exploration tools aimed at locating lineaments in the area. He further observed several significant lineaments directions are presented in W-E, ENE and E-W, The directional fractures originated from several faults zones (Entuba, Deka, and Inyantue) and suggested to be splays from the main faults. Isachien (1978, 1994, 2018) posited the 4-stage detailed investigative procedure for extracting and identifying geological information from landsat image products. They based their studies on brittle deformation in the Adirandack mountains and produced structured map of all the linear features that are clearly visible on landsat image.

Warne, (1978) in a research conducted by the Australian National University exploreD the extent to which landsat Mss image is used. He confirmed and endorsed the technique in principle and demonstrated a number of implementation difficulties. To overcome the problem, he recommended an integrated approach involving satellite image computer based analysis, human imput, reference level based interpretation and ground truth collection. Their relationships were synthesized to develop structural and stratigraphic interpretation.

In the study carried out by Mkwete et al. (1986) work on the Eastern Adamawa plateau, central Cameroun with digitally processed Landsat MSS image and aerial photographs, found that fracture traces and fracture intersections, chemically altered rock, alluvial deposits along with lineament are indicative of localized groundwater concentration in the area. Here, five areas with each characteristics have been noted as potentially suitable for location of ground water in fissures, fissured zone, in areas of deeply indurate crust and beneath alleviate deposits.

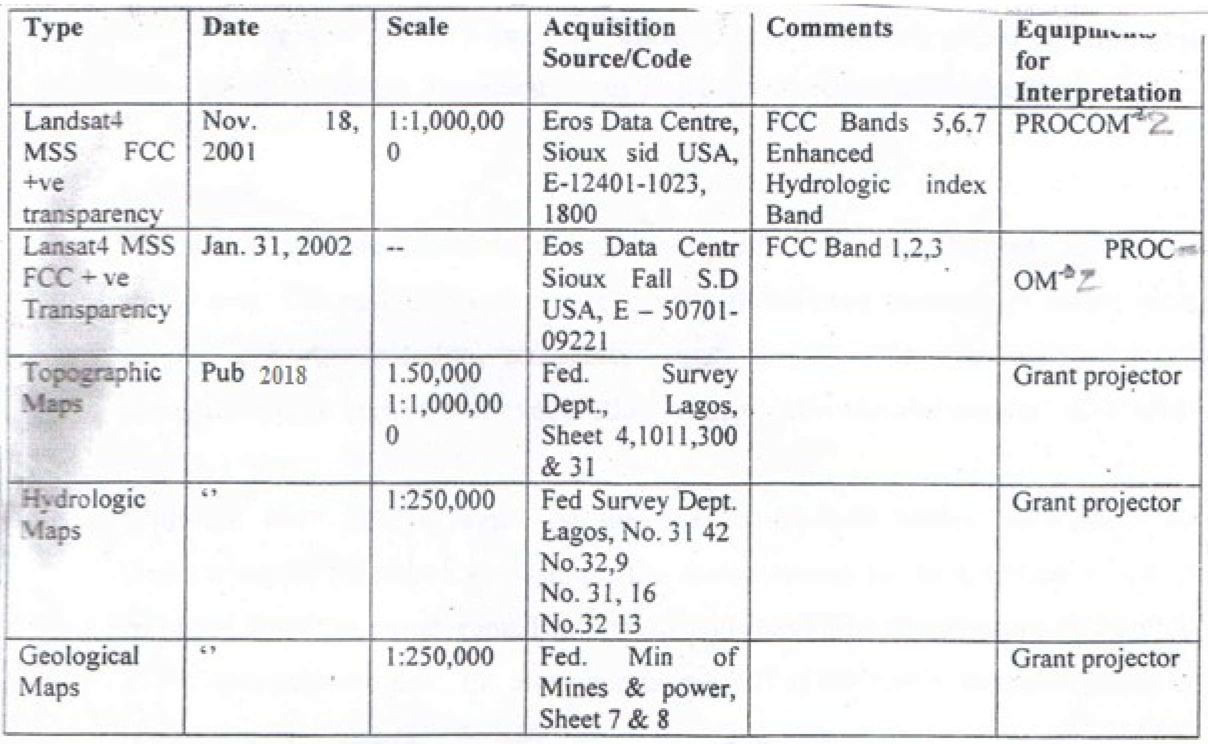
Landsat ETM-7 images of band 5 were used by Anwai et al., (2013) and found to be the most suitable band in automatic delineation. He preferred manual technique as it allows a higher degree of operator's control despite the fact that it is more time-consuming and subjective. According to Ramli et al., (2009) in his reviewed works on lineament mapping and its application in landslide hazard, noted that most the studies are based on aerial photos and satellite images are analized with either digital or manual analysis methods. Most researchers prefer manual technique as it allows human imput and a higher degree of operator's control (Ali and Phrasteh, 2004) despite the fact it is time involving and subjective. Anwar et al. (2013) stated that ETM enhanced Landsat satellite image, band 5 is found to be most suitable in automatic delineation of lineaments on satellite image as they have higher spatial resolution (30m) for study and analysis. Maged and Naziani, (2010) worked on lineament mapping using Landsat Thematic Mapper (TM) satellite data and observed that geological feature such as lineament and faults are key parameters used to describe the earth's generated disaster mechanism and are identified as significant indicator for oil and water deposits for exploration. Furthermore, Mogaji et al., (2011) also worked in the South Western Basement Complex of Ondo State, Nigeria by mapping lineament for groundwater targeting to illustrate the application and importance of remote sensing and GIS for efficient ground water resource exploration and management. He used landsat ETM$^+$ with geological maps for identification, mapping and analysis of lineament for groundwater targeting for which most of the wells are reported productive.

Vijoen and Vijoen (2018) on the selection of landsat data for geologic, geomorphic and hydrologic purposes; stated that images acquired just after wet/rainy season or post winter periods based on global best practices, are recommended for this purpose as they tend to show more details than any other period.

IV. RESEARCH METHOD

The research method employs digitally processed satellite image data, well enhanced for manual analyses as in the works of Chevasa, (1999) and Newton, (2007). The image data sources and their characteristics obtained in December and January respectively are employed for this research study is shown on Table 1. The research principally emphasises and employs manual analysis of remotely sensed data satellite image as the primary sources of data. Other data for this study consist of existing secondary information on the area include: climatic data from meteorological Stations, topographic maps, form the Federal Survey's and geologic maps from Federal Ministry of Mines and Power. The landsat imageries of hydrologic bands 5, 6 and 7 that reveal geologic features are used.

Table 1 Showing Data Sources and Characteristics



Type	Date	Scale	Acquisition Source/Code	Comments	Equipment for Interpretation
Landsat4 MSS FCC +ve transparency	Nov. 18, 2001	1:1,000,000	Eros Data Centre, Sioux sid USA, E-12401-1023, 1800	FCC Bands 5,6.7 Enhanced Hydrologic index Band	PROCOM^{2}2
Lansat4 MSS FCC + ve Transparency	Jan. 31, 2002	--	Eos Data Centr Sioux Fall S.D USA, E – 50701-09221	FCC Band 1,2,3	PROC- OM^{2}Z
Topographic Maps	Pub 2018	1.50,000 1:1,000,000	Fed. Survey Dept., Lagos, Sheet 4,1011,300 & 31		Grant projector
Hydrologic Maps	‘’	1:250,000	Fed Survey Dept. Lagos, No. 31 42 No.32,9 No. 31, 16 No.32 13		Grant projector
Geological Maps	‘’	1:250,000	Fed. Min of Mines & power, Sheet 7 & 8		Grant projector

Source: Field trip, (2019)

The methodology involved data collection and analysis for structural map production using the image evaluated using secondary data, topographical map and geologic maps The ground truthing (field observation) is finally used to distinguish and establish the rock boundaries and identify lineaments.

The component of the methodological framework is explained as follows: The landsat MSS is enlarged using Procom 2, a specialized projection compositor equipment (donated by Canadian government to Geography Department, University of Lagos) that plannimetrically registers the projected images on a projected topographical base map. The equipment projects image transparencies to the base map at optional scales in line with Gregory Geosciences Procom manual of 1984. The features are directly delineated and allocated into known categories on a transparent overlay to correspond with area(s) of uniform characteristics of the interpretative elements. These are limited, exclusive and exhaustive in a domain separated by a discontinuity in the range of observed properties (Imbrue and Purdy, 1962) to define the unit (class). Lineament identification are carried out for structural mapping (within the concept of geologic and geomorphic mapping), relies on reference level (professionalism), recognition and identification of the units on the transparent overlay of the image, based on basic identification element and a number of criteria. The manmade lineament such as roads, rail cuttings, lithological lineament produced by lithological contracts and features were validated and avoided based on topographic and geologic mapping procedure for identification of lineament mapped ..

V. RESULT

Geologic Mapping:

The procedure for mapping is to plot directly onto a transparent overlay on the projected base map. The rock boundaries and features interpretations were carried out to finally establish the boundaries for compilation of discerned rocks, features and structures. The secondary data are used in identify lineament structures (to eleminate other man made features) and change them to solid line on the interpretative base map. The rocks are identified with Oyawoye (1970) classification scheme and nomenclature of the rocks types in the area, is adopted and used for geologic and geomorphic presentations of this research work.

Geomorphologic Indicators:

This is the study of surface rocks features of the terrain by means of the satellite images. The distinctive forms and character of the landforms are attributed to dominating features and structures that result from a particular process and they normally persist to the limit of the lithologic boundaries. There established a discontinuity defined by break in slope, identified by visible colour boundary are further used to delineate the geologic boundaries.

The geologic and geomorphic analyses used the basic elements of interpretation to delineate the boundaries between the rock units in the area. The entire interpretative mapping process used international acceptable rock symbols, are indicated on the structural map produced. These analyses aided the entire interpretative mapping process.

Ground Truthing:

The laboratory analyses of the image carried out for structural data on the geologic rocks, identified various lineaments which are further established to conform with ground truthing. The field observations made include these on geology, hydrology and vegetation characteristics that helped to infer the subsurface phenomena. This was conducted during pre and post mapping process and undertaken to confirm the mapped units and lineaments and lineament zones. Few of them are not visible in the field and there are noticeable chemically altered rock, alluvial deposits along with the mapped lineaments, which are found to indicate localized concentration of subsurface water deposits. This is based on observation of the numbers of active boreholes sunk in the area. Furthermore, in the field, rock samples were collected and mapped, visually analyzed and identified in the laboratory and are found to confirm and conform with Oyewoye (1970) classified rock types.

It has been established that unless ground truth is available, image tones and textures have the lowest relative confidence and reliability as indicators of the surface features used to infer those found underground in an enhanced satellite image

Analysis

Data obtained using landsat images are due to varying radiation recorded by the sensor for different rock units, structures, water bodies and other features on rock surface which are of significance to the structural mapping process. There include lineaments outline and their zones mapped, density, frequency, direction and rocks mapped and their boundaries, amongst others. The landsat image projected has various shades of colours on the base map for which the terrain properties are correlated and mapped.. The proposed identification keys based of manual analyses using basic elements of interpretation for identification of features to which the terrain properties are correlated in mapping them in the study area are presented in Table 2. The relationships of the mapped lineaments were synthesized to develop structural and stratigraphic interpretation. It is found that, fracture traces and fracture intersections are discernibly mapped (with encircled dotted lines).

The lineaments mapping led to delineation of ground water localised zones and are mostly feasible for further geo-physical survey, prospecting for sitting of productive and sustainable supply boreholes. It is found that of the 20 boreholes (with 4 in each segmented parts A-E) sunk, are found prospective 15 active boreholes (with 3 in each segmented parts A-E) constituting 75% of the total considered the area. The zones therefore, possess the characteristics and potentials suitable for location of ground water reservoirs in fissures, fissured zone, in areas of deeply indurated crust and beneath alluvial deposits.

The interpretation, mapping and analyses of the satellite Image indicated that some rocks are found together with identical mineralogy e.g. granite, aplite with meta-gabbro, hornblende schist with meta-sediments, meta-gabbro and hornblende are difficult to identify and only possible with the integration of secondary data.

These are further presented below:

Rock Boundaries:

The image provides varying shades of colour corresponding with an exhaustive to the limit of rock boundaries, and rock types for geologic map productions. This is exhibited by sharp colour contrast between the two rock types. For example, there is a very sharp contact of light blue colours between the metasediments (SP) and the granite gniss (GG) whose colours are respectively brown and light pink. Also, there is yellow colour at the contact between the older granite (OGD) and the meta conglomerate that have light red and deep brown colours respectively. The colour differentiation contacts in rocks are due to intersectional admixture of combined rock types radiation, whose composition is reflected at the boundaries (fig 2 in Appendix 2)

Lineament Mapping: The dislocation on rock are clearly visible on landsat image. The pattern of their distribution within the ferruginous quartzite aided their mapping. The rocks develop low tensile strength that resulted from tectonism. The general orientation of the mapped fault direction and frequencies are indicatives of the general strike of the rock which is in NNE-SSE at an angle of 10-30^0 (fig 3 in Appendix 2).. This data are used for structural map of the area (fig 4 in Appendix 2).

Rivers: The radiation from the water body is light blue, while the minor river is light yellow. The tonal variation from the river system is probably due to the high reflection of the latter presence of sandstones on the streams and river channels. The rivers are part of Bakolori Dam Reservoir are discernibly mapped using the satellite image (fig 2 in Appendix 2)...

Roads: The existing roads accurately register these on base maps without additional road detected. The major roads indicated deep yellow colour, while the minor ones are pale yellow colours (fig. 2 in Appendix 2).

VI. CONCLUSION

The various lineaments in the basement complex rocks have their outline clearly defined and napped with the images .The general pattern of clearly mapped fault direction and frequency and to show the general strike of rocks in NNE-SSE at an angle of 10-30^0 in the structural map. Furthermore, with the numerous lineaments- faults and fault traces mapped, it indicated hat areas of major dislocation with intersectional lineament, are prospective areas concentration of water accumulation where ground water occurrence is mostly feasible for further survey, prospecting and drilling for sustainable water supply in the area.

The lineaments mapping in the area led to delineation of ground water localised zones. It is found that of the 20 boreholes in the area (with 4 in each segmented parts A-E), 15 active boreholes (with 3 in each segmented parts A E) constituting 75% of the totals are found to be productive.

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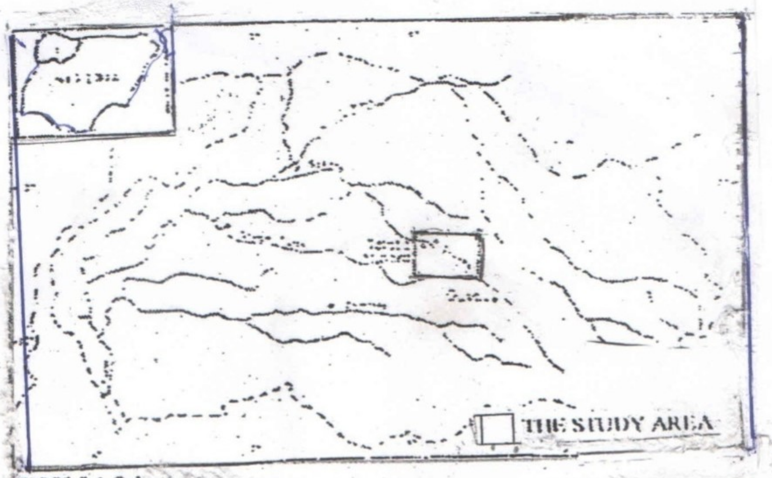
Appendix 1



SOURCE F A O .

FIG 1: MAP SHOWING THE SOKOTO RIMA BASIN

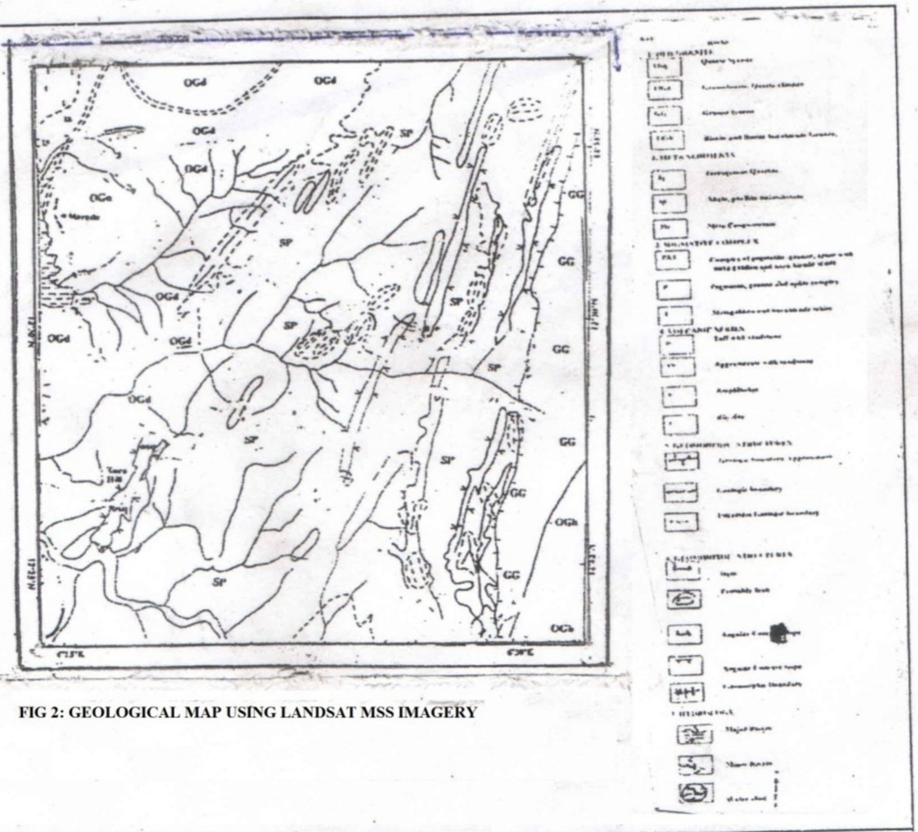
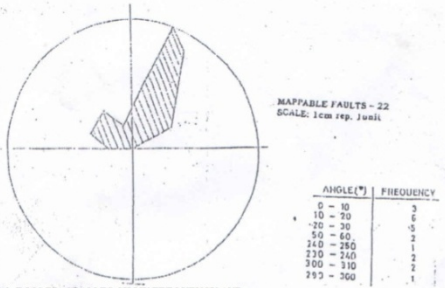


FIG 2: GEOLOGICAL MAP USING LANDSAT MSS IMAGERY

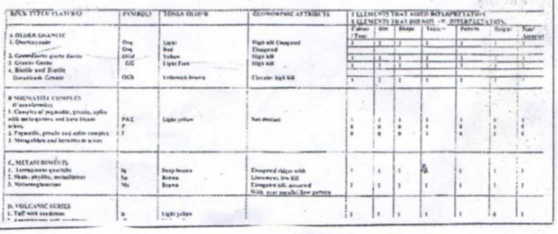
Appendix II


MAPPABLE FAULTS - 22
SCALE: 1cm rep. 1unit

ANGLE(°)	FREQUENCY
0 - 10	3
10 - 20	6
20 - 30	5
50 - 60	2
240 - 250	1
230 - 240	2
300 - 310	2
293 - 300	1

FIG 3: ROSS DIAGRAM TO SHOW FREQUENCY AND DIRECTION OF FAULTS OF PRODUCED MAP

TABLE 4: SHOWING LANDSAT IMAGERY INTERPRETATIVE KEY



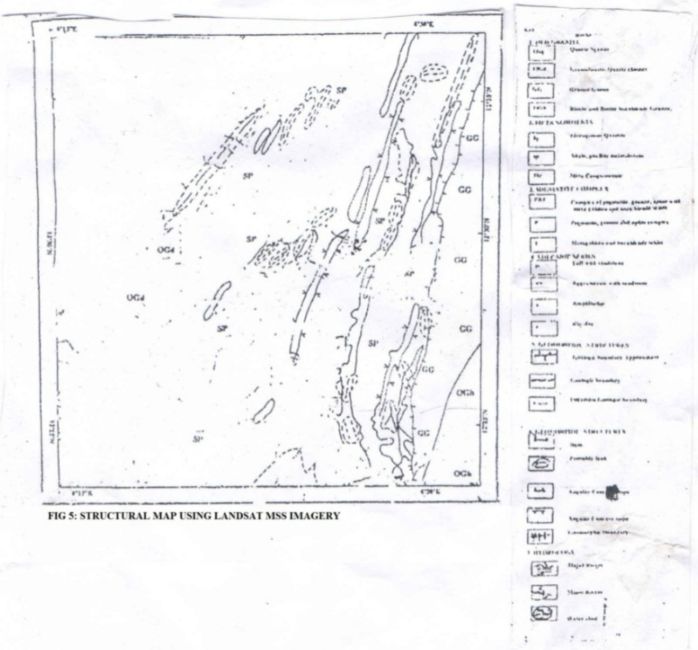


FIG 5: STRUCTURAL MAP USING LANDSAT MSS IMAGERY